

1 **EFFECTS OF SESAME SEED ENRICHMENT ON PHYSICO-CHEMICAL AND**
2 **NUTRITIONAL CHARACTERISTICS OF FLOUR FROM TWO VARIETIES OF**
3 **WHITE YAM CULIVARS (Scientific name and authority?)**

4
5 **ABSTRACT**

6
7 The effects of enriching two cultivars of varieties of white yam (*Dioscorea rotundata*
8 Autho?) flour with sesame seed (*Sesamum indicum* Autho?) flour on their physico-chemical
9 and nutritional characteristics were studied. Yam flours were produced from *Abuja* and *Efuru*
10 yams by parboiling at 60°C for 10 minutes and left overnight, followed by sun drying for four
11 days. Enriched yam flour samples were prepared by thoroughly mixing the yam and sesame
12 seed flour in ratios 95:5, 90:10, 85:15 and 80:20 respectively. Proximate, mineral and anti-
13 nutrient content as well as functional properties of enriched flours were determined using
14 standard methods of AOAC. The two yam flour samples were low in moisture, crude
15 protein, fat and ash content, high in carbohydrate and macro minerals, while Sesame seed
16 was very low in moisture and carbohydrate, and low in crude fibre content, but very high in
17 crude protein, fat, ash and macro minerals. The moisture, crude protein, fat and fibre, ash and
18 carbohydrate content of the yams and enriched samples ranged between 11.9-13.8g, 3.3-7.5g,
19 0.5-13.8, 1.6-3.0 g, 2.0-2.6 g and 61.7-78.8 g/100g respectively. Addition of sesame seed
20 flour resulted in reduction in moisture and carbohydrate content and significant increase
21 (p<0.05) in protein, fat and ash values of enriched samples. The protein, fat and mineral
22 content of the enriched samples increased with increased level of sesame seed flour inclusion
23 (p<0.05). Both yam and sesame flours were low in the antinutritional factors studied. Sesame
24 flour was high in trypsin inhibitors and polyphenols. Enrichment with sesame flour resulted
25 in further reduction in the antinutritional factors content with increase in trypsin inhibitors
26 and polyphenols content of the products. *Efuru* variety flour with its enriched products had
27 higher water and oil absorption capacity, loose and packed bulk density and swelling capacity
28 than *Abuja* variety flour. Enriching yam flour with sesame flour can improve the nutrients
29 and functional properties of their products which can improve the nutritional status, health
30 and well-being of consumers.

31
32 **Key words:** Yam flour, Sesame seed flour, Anti-nutritional factors, Food enrichment,
33 Physico- chemical properties

34
35
36 **INTRODUCTION**

37 Sesame (*Sesamum indicum* L.) also known as sesamum or beniseed, is a member of the
38 family *Pedaliaceae*, and one of the most ancient oilseed crops with high level of antioxidants
39 [1]. Sesame seeds are highly valued for their high content of oil, which is very resistant to
40 rancidity, and used as cooking oil. It plays important role in human nutrition, medicinal,
41 pharmaceutical, industrial and agricultural uses [2], [3].

42 Sesame foods are very healthy and are popular in culinary preparation. After the extraction of
43 its oil, the cake is mostly used [for as](#) livestock feed or often as manure or the seed is ground
44 into sesame flour and added to health foods [2]. Sesame seed[s](#) contains significant amount of
45 sesamin and sesamolins, both of which have beneficial effects on serum lipid levels and liver
46 function, and give sesame seed oil a marked antioxidant activity [4]. Sesame seed also
47 contains phenolic compounds and tocopherols with antioxidant activity that have significant
48 effect on reducing blood pressure, lipid profile, degeneration of vessels and impact in
49 reducing chronic diseases [5]. The oil from sesame seed contains about 35%
50 monounsaturated fatty acids and 44% polyunsaturated fatty acids [3], [6]. In addition to being
51 a good source of oil, the seed[s](#) also contain significant amount of protein (18-25%),
52 carbohydrate (13.5%) and ash (5%) [7]. The protein of the seed has immobilized amino acid
53 profile with good nutritional value similar to soybean [8].

54 Yam, [belonging to the](#) (*Dioscorea* [genus spp.](#)), constitutes staple food that produces edible
55 starch, and is the third most important tropical root crop after cassava and sweet potato [9].
56 *Dioscorea species* is the most important food crop in West Africa, with Nigeria being the
57 highest producer worldwide (71% of the world's total production [10]; and they serve as
58 important source of energy for millions of people in Nigeria [11], [12], [13]. It has higher
59 levels of protein and vitamins than cassava [13].

60 Among the many varieties of yam species widespread through the humid tropics, White yam
61 (*Dioscorea rodundata*), Yellow yam (*D. cayensis*), Water yam (*D. alata*), Chinese yam (*D.*
62 *esculanta*), Aerial yam (*D. bulbifera*) and Trifoliate yam (*D. dumentorum*) are the most
63 economically important ones [14]. White yam (*D. rodundata*) is the most preferred yam
64 species [\(ref.?\)](#). The tubers are processed into chips, boiled yam, roasted yam, pounded yam,
65 porridge or yam flour through frying, boiling, roasting, pounding, steaming, or fermentation
66 followed by milling respectively [15]. In addition to its importance in diets, it is prominent in

67 traditional festivals, marriages, burials and indeed in almost all social, cultural and religious
68 gatherings [13].

69 White yam is low in protein and micronutrients, especially vitamins, and large quantity of
70 these micronutrients are lost during processing [16], [17]. Addition of sesame seed to yam
71 products can provide a means of improving the nutrient content of the products as well as
72 nutrient intake of consumers. This study was carried out to investigate the effect of enriching
73 the flour of two cultivars of white yam (*Abuja* and *Efuru*) with sesame seeds on the physico-
74 chemical properties of the products.

75 MATERIALS AND METHODS

76 Sample Collection and Preparation

77 Two varieties cultivars of *Dioscorea* *D. rotundata* (*Abuja* yam and *Efuru* yam) with white
78 sesame seeds were purchased from Bodija market in Ibadan, Oyo State, South-west Nigeria.
79 Bodija market is one of the largest markets for foodstuff in Ibadan, and is the major depot for
80 raw foods from different parts of the country. Hence, samples obtained from this market is
81 representative of food items from most parts of the country. The tubers were washed to
82 remove the dirt and adhering sand particles, rinsed with clean water at room temperature. The
83 washed tubers were peeled with knife, washed with distilled water and cut into pieces for
84 each of the *Abuja* and *Efuru* varieties yam, sliced into cubes with dimension 1.0×1.5×1.5 cm
85 to ensure efficient heat circulation during drying.

86 The two yam varieties slices were washed with distilled water, weighed and parboiled at
87 60°C for 10 min, left in the warm water for 18 h, drained and sundried for 4 days separately
88 [18], [16]. The different dried yam slices were milled into flour using attrition mill, the flour
89 samples were packaged in sealed transparent polythene bags and labeled as *Abuja* yam flour
90 (AYF) and *Efuru* yam flour (EYF) respectively; and stored at room temperature in a cool, dry
91 place till when needed. Similarly, the white sesame seeds were cleaned manually to remove

92 dirt, foreign materials, and immature and damaged seeds. The cleaned seeds were crushed
93 into smaller particles in a glass mortar and stored in plastic bags at 40°C in an oven until
94 when needed.

95 Different ratios of yam flour and sesame seed flour were formulated as follows.

- 96 Sample 1 = 95 g of *Abuja* yam flour + 5 g Sesame seed flour
97 Sample 2 = 90 g of *Abuja* yam flour + 10 g Sesame seed flour
98 Sample 3 = 85 g of *Abuja* yam flour + 15 g Sesame seed flour
99 Sample 4 = 80 g of *Abuja* yam flour + 20 g Sesame seed flour.
100 Sample 5 = 95 g of *Efuru* yam flour + 5 g Sesame seed flour
101 Sample 6 = 90 g of *Efuru* yam flour + 10 g Sesame seed flour
102 Sample 7 = 85 g of *Efuru* yam flour + 15 g Sesame seed flour
103 Sample 8 = 80 g of *Efuru* yam flour + 20 g Sesame seed flour.

104

105 Each sample was thoroughly mixed, packed, labeled and sealed in transparent polythene bag.

106 All the ten labeled samples were kept at 4°C in the refrigerator in the laboratory until required
107 for analyses [19].

108 **Proximate analysis**

109 The moisture content was analyzed using the Association of Official Analytical Chemists'
110 (AOAC) approved method 967.08, crude protein by AOAC method 988.05, crude fat or ether
111 extract, ash and crude fibre contents were determined using the AOAC methods 2003.06,
112 942.05 and 958.06 respectively [20]. Carbohydrate content was determined by difference and
113 all analyses were carried out in triplicate.

114 **Mineral [a](#)Analysis**

115 The concentrations of the minerals in the yam flour, sesame flour and enriched sample flour
116 were determined by Atomic Absorption Spectrophotometric method (AOAC, 975.11) [20].

117 Vanado-molybdate colorimetric method was used to determine phosphorus (AOAC, 975.16)
118 [20]. All the measurements were made in triplicate.

119 **Determination of anti-nutritional factors**

120 **Phytate determination**

121 Phytate was determined by weighing 2_g of each sample into 250_ml Erlenmeyer flask. A
122 100ml of 2% hydrochloric acid was added to soak each sample for 3 hours. This was filtered
123 through a double layer of filter paper. About 50_ml of each filtrate was placed in a 500_ml
124 flask and 107_ml distilled water added in each case, followed by addition of 10ml of 0.3%
125 ammonium thiocyanate (NH₄SCN) solution. . The resultant solution was then titrated with
126 standard solution of iron (III) chloride containing 0.00195_g iron per ml till a slightly
127 brownish-yellow colouration which persisted for 5 minutes **persisted** (AOAC method
128 986.11) [20].

129 **Saponin determination**

130 Saponin content was determined using Spectrophotometric method described by Brunner,
131 [21]. The absorbance of the sample as well as standard saponin solutions were read after
132 colour development in a Jenway V6300 Spectrophotometer at a wavelength of 380_nm.

133 **Tannin determination**

134 Total tannin content was determined by the Spectrophotometric procedure described by
135 Association of Official Analytical Chemists [22].

136 **Oxalate determination**

137 The oxalate content of the samples was determined using the AOAC method [20].

138 **Determination of functional properties of flour**

139 **Swelling cCapacity dDetermination**

140 This was determined in accordance with the method described by Leach *et al.*, 1959 [23] with
141 modification for small samples. A 0.1g of sample was weighed into a weighed test tube (W₁)

142 into which 10 ml of distilled water was added and heated in a water bath at temperature of
143 60°C for 30 min, with constant shaking within the heating period. The mixture was cooled to
144 room temperature and centrifuged at #5000 × g, for 15 minutes. The residue obtained after
145 centrifuging with the water was retained and the test tube was weighed (W₂).

146 Swelling of starch = $\frac{W_2 - W_1}{\text{Weight of starch}}$
147

148 | **Least gGelation cConcentration (LGC) dDetermination**

149 Sample of starch (2 - 18% w/v), were prepared in test tube with distilled water (5ml). The
150 starch suspensions were mixed with Variwhirl mixer for 5 min. The test tubes were heated for
151 30 min at 80°C in a water bath, followed by rapid cooling under running cold tap water. The
152 test tubes were further cooled at 4°C for 2_hrs. Least gelation concentration was determined
153 as that concentration when the sample from the inverted test tube did not fall down or slip.

155 | **Oil and wWater aAbsorption cCapacity dDetermination**

156 The Sathe *et al.*,(year?) [24] method was applied. A 5 ml of oil (Executive Chef Oil, Lever
157 Brothers (Nigeria) Plc, Lagos, Nigeria) was added to 0.5_g of sample flour in 10 ml
158 centrifuge tube. The mixture was stirred with glass rod to disperse the sample in oil for 30 s
159 and centrifuged for 30 min at 35000_rpm. Then, the volume of the supernatant was recorded.

160 | **Loose and pPacked bBulk dDensity dDetermination**

161 Two grammes (2 g) of flour was weighed into a 25 ml measuring cylinder as volume_1 (V₁),
162 the flour particles inside the cylinder was tapped several times for 10 min till a constant
163 volume_2 (V₂) was obtained. Loose bulk density was obtained using the formula:

164 Bulk Density = $\frac{\text{Weight of sample}}{\text{Volume } V_1}$
165

166 while

$$\text{Packed bulk density} = \frac{\text{Weight of sample}}{\text{Volume } V_2}$$

Statistical analysis

Analyses were done in triplicate. Analysis of variance was performed to calculate the significant difference between means, and multiple range test (Turkeys Least Significant Difference) was conducted on the results obtained. Level of significance was set at $p < 0.05$.

RESULTS

Proximate composition

The proximate composition of raw flour of the two varieties of yam, sesame seed and the enriched yam flour are presented in Tables 1a & 1b respectively. The moisture content of the two varieties of yam flour was low and very similar without significant difference ($p > 0.05$). The crude protein and fat content of the flour of the two yam varieties were low, while the ash content was high, and total carbohydrate content very high compared with other tubers. *Efuru* flour was slightly but innot significantly higher ($p > 0.05$) in crude protein and ash values. Sesame seed flour was very low in moisture and carbohydrate content, high in crude protein and very high in fat compared with the two yam varieties. Enriching the yam flour with sesame seed flour significantly reduced the moisture and total carbohydrates content ($p < 0.05$), the level of reduction increasing with the level of inclusion of the seed flour. The moisture content of all enriched samples of yam flour was lower than that of flour of the two varieties of yam, but higher than that of sesame seed flour. There were significant increase ($p < 0.05$) in protein, fat and ash content of enriched samples, the value of nutrients increasing with increase in level of inclusion of sesame seed flour.

Mineral cComposition

The mineral content of the flour of the two varieties of yam, sesame seed and enriched yam flour are **as** presented in Tables 2(a) and (b). The yam varieties were high in potassium, calcium, magnesium and phosphorus, moderate in iron, and zinc, but very low in manganese and copper content (Table 2(a)). The *Efuru* yam flour was **innot** significantly higher ($p>0.05$) in **minerals all the minerals** than that of *Abuja* yam flour. Sesame seed flour was very high in all the macrominerals studied. Enriching the yam flour with sesame flour resulted in significant increase in all the minerals, especially the macrominerals.

Anti-nutritional and antioxidant composition

The anti-nutritional factors and antioxidant properties of the yam flours and enriched samples are presented in Tables 3. The two yam **varieties cultivars** were very low in antinutritional factors, reducing power and polyphenols, while sesame seed had significantly higher **value** ($p<0.05$) **values** of the antinutrients. Likewise, sesame seed contained significantly higher values of trypsin inhibitors, reducing power and polyphenols ($p<0.05$).

Functional Propertiesproperties

The functional properties of the yam flours and enriched samples are as **shown presented** in Tables 4. The loose bulk density ranged from 0.49 g/ml in raw flour of the two varieties of yam and 0.51 g/ml in sesame seed and in the mixtures above 5% proportion while in the packed bulk density, the range was between 0.51 g/ml – 0.54 g/ml. The water absorption capacity was higher in *Efuru* yam flour than in *Abuja* yam flour as well as its enriched samples.

DISCUSSIONS

Proximate composition

The two yam flours were low in moisture content (Table 1(a)). Low moisture content of the two yam flour is indicative of its long shelf life, as it has been reported that low moisture

content reduces microbial spoilage of food products [25]. The value obtained for moisture content of flour in this study were higher than the range of 3.33 – 6.42% reported for banana – sesame seed blend [26].

The protein and fat values of the yam flour were low. This is in line with the finding of Adepoju [16] that raw yam is low in both protein and fat content. The high ash content of the two yam flour was suggestive of high mineral content, especially macro-minerals. The result obtained here is in agreement with the reported ash values of some processed white yam products [16].

The value obtained for sesame seed flour proximate composition in this study is at variance with the one in the literature [27]. The difference in value is believed to be due to yearly, seasonal and geographic variation, as both samples were obtained from different geographic locations and years.

Addition of sesame seed flour to the yam flours improved the nutrient content of the products (Table 1(b)). The observed increase is believed to be due to the high nutrient content of sesame seed ([27], [28], [29]). However, the addition resulted in reduction of total carbohydrate content. The reduction is believed to have resulted in low carbohydrate and high protein and fat contents of the seeds [27].

Table 1a: Proximate composition of *Abuja* yam, *Efuru* yam and Sesame seed flour (g/100g)

Parameter	AYF	EYF	SSF
Moisture	13.8±0.01 ^d	13.7±0.01 ^d	2.9±0.00 ^a
Crude Protein	3.3±0.00 ^c	3.5±0.01 ^d	25.9±0.00 ^b
Crude Lipid	0.5±0.18 ^b	0.5±0.00 ^b	53.0±0.02 ^d
Ash	2.0±0.00 ^d	2.2±0.01 ^a	5.7±0.00 ^b
Total Carbohydrates	80.4±0.00 ^b	80.1±0.01 ^b	12.5±0.01 ^d

236

237 AYF = *Abuja* yam flour; EYF = *Efuru* yam flour, and SSF = Sesame seed flour

238 Table 1b: Proximate composition of enriched *Abuja* and *Efuru* yam flour (g/100g dry sample)

Parameter	Moisture	C. Protein	C. Lipid	Ash	T. Carbohydrates
Sample 1	12.3±0.06 ^d	6.7±0.02 ^d	13.4±0.01 ^b	2.3±0.01 ^a	65.3±0.01 ^a
2	12.3±0.01 ^d	6.8±0.03 ^a	13.4±0.01 ^c	2.4±0.01 ^c	65.0±0.01 ^b
3	12.2±0.01 ^d	6.9±0.03 ^b	13.5±0.04 ^a	2.4±0.01 ^b	65.0±0.01 ^d
4	12.0±0.01 ^b	7.1±0.08 ^d	13.5±0.04 ^b	2.5±0.01 ^b	64.9±0.01 ^d
5	12.3±0.00 ^a	6.9±0.00 ^b	13.5±0.00 ^a	2.4±0.01 ^c	64.9±0.01 ^b
6	12.2±0.01 ^b	7.1±0.00 ^d	13.6±0.00 ^b	2.4±0.01 ^c	64.7±0.01 ^a
7	12.1±0.01 ^b	7.3±0.01 ^b	13.7±0.00 ^a	2.5±0.01 ^d	64.4±0.01 ^b
8	11.9±0.01 ^a	7.5±0.01 ^c	13.8±0.01 ^d	2.6±0.00 ^a	64.2±0.01 ^a

239 Sample 1 = 95 g of *Abuja* yam flour + 5 g Sesame seed flour

240 Sample 2 = 90 g of *Abuja* yam flour + 10 g Sesame seed flour

241 Sample 3 = 85 g of *Abuja* yam flour + 15 g Sesame seed flour

242 Sample 4 = 80 g of *Abuja* yam flour + 20 g Sesame seed flour.

243 Sample 5 = 95 g of *Efuru* yam flour + 5 g Sesame seed flour

244 Sample 6 = 90 g of *Efuru* yam flour + 10 g Sesame seed flour

245 Sample 7 = 85 g of *Efuru* yam flour + 15 g Sesame seed flour

246 Sample 8 = 80 g of *Efuru* yam flour + 20 g Sesame seed flour.

247 T carbohydrates = Total carbohydrates

248 [C. protein and C. Lipids were not defined in the key](#)

249 Table 2a: Mineral composition of *Abuja* yam, *Efuru* yam and Sesame seed flour (mg/100g)

Parameter	AYF	EYF	SSF
Potassium	215.00±0.01 ^d	217.00±0.02 ^d	1234.70±0.00 ^c

Sodium	57.67±0.02 ^a	60.00±0.02 ^b	587.00±0.06 ^d
Calcium	137.00±0.05 ^c	136.00±0.04 ^c	1160.10±0.04 ^a
Magnesium	274.00±0.01 ^b	277.00±0.05 ^d	393.60±0.05 ^d
Phosphorus	226.00±0.02 ^d	228.00±0.02 ^a	480.40±0.02 ^b
Iron	3.13±0.01 ^d	3.10±0.01 ^b	9.26±0.03 ^c
Zinc	1.87±0.01 ^d	1.86±0.01 ^a	3.38±0.01 ^d
Manganese	0.43±0.01 ^c	0.40±0.00 ^d	0.76±0.01 ^a
Copper	0.29±0.01 ^a	0.29±0.02 ^c	0.48±0.03 ^b

250
251 The yam flour had good potassium and sodium ratio for balancing the intra and extracellular
252 fluid of the body. Sesame flour is a very good source of these minerals (Table 2(a)). A 100 g
253 sample of sesame flour can meet more than half of daily requirements of the macro-minerals
254 and zinc. The mineral content of the enriched samples increased with the level of inclusion of
255 sesame seed flour. The increase in essential minerals content of enriched samples can be
256 attributed to the fact that sesame seed is a good source of protein minerals. Studies have
257 reported that legumes and nut seeds are good sources of protein and minerals, and that these
258 seeds are usually consumed in many parts of the developing countries, particularly where
259 animal proteins are scarce or very expensive ([30], [31]).

260

261 **Anti-nutritional and antioxidant composition**

262 The level of antinutritional factors in the sesame seed influenced the amount of trypsin
263 inhibitors and antioxidant properties of the enriched samples (Table 3). However, the trypsin
264 inhibitors concentration can be eliminated or reduced to tolerable level through processing
265 methods like roasting, fermentation, soaking etc. ([32], [33], [34], [35]). The enriched flour

266 | samples will undergo processing before they are being consumed., **h**Hence, the enriched
267 | flours are safe for consumption.

268 | The presence of high quantity of polyphenols is an indication of good antioxidant properties
269 | of sesame seed, as well as the enriched products.

270 | The WAC? (Define the accorynm at first mention) values of the yam flour and enriched
271 | samples were comparatively lower than the value of *Cassia fistula* seed flour reported by
272 | Akinyede and Amoo [36]. The swelling capacity of the two varieties of yam was higher than
273 | the sesame seed with a slight increase with the % increase of sesame seed flour. However, the
274 | swelling capacity of the fortified yam flour was significantly lower than both the *Abuja* and
275 | *Efuru* yam flours. The least gelation concentration of the enriched yam flour also increased
276 | with successive increase in the amount of sesame seed flour though the raw yam flour had
277 | higher values when compared with sesame seed flour. The high gelation value implies that
278 | the diet would require more energy consumption to cook, and hence, the gel strength of the
279 | diets would be weak and undesirable [37].

280

281 | Table 2(b): Mineral composition of enriched *Abuja* and *Efuru* yam flour (mg/100g)

Sample	1	2	3	4	5	6	7	8
K	346.30	359.40	396.70	413.00	305.00	358.30	399.70	415.00
	±0.06 ^a	±0.04 ^a	±0.03 ^a	±0.02 ^c	±0.02 ^b	±0.01 ^c	±0.05 ^b	±0.02 ^c
Na	127.30	154.00	173.00	187.70	130.00	157.00	175.70	190.30
	±0.10 ^b	±0.02 ^c	±0.01 ^d	±0.01 ^a	±0.01 ^a	±0.02 ^a	±0.02 ^a	±0.04 ^b
Ca	290.30	305.30	336.30	354.30	291.70	309.00	340.00	359.30
	±0.06 ^c	±0.05 ^d	±0.01 ^c	±0.04 ^b	±0.04 ^d	±0.02 ^a	±0.04 ^c	±0.02 ^d
Mg	296.00	310.70	323.00	337.30	300.70	311.70	324.70	340.30
	±0.02 ^d	±0.04 ^a	±0.02 ^d	±0.05 ^b	±0.06 ^a	±0.04 ^c	±0.02 ^b	±0.05 ^c

P	270.70	287.30	302.30	315.30	274.00	290.30	305.70	316.70
	±0.04 ^a	±0.02 ^b	±0.05 ^b	±0.02 ^d	±0.02 ^c	±0.00 ^d	±0.02 ^d	±0.04 ^a
Fe	3.20	3.20	3.24	3.27	3.20	3.21	3.24	3.27
	±0.01 ^c	±0.04 ^b	±0.02 ^c	±0.01 ^a	±0.01 ^b	±0.01 ^a	±0.01 ^a	±0.04 ^a
Zn	1.92	1.97	1.99	2.02	2.00	1.97	2.00	2.02
	±0.01 ^a	±0.01 ^a	±0.01 ^a	±0.02 ^c	±0.01 ^c	±0.01 ^b	±0.01 ^c	±0.01 ^b
Mn	0.45	0.48	0.47	0.50	0.45	0.49	0.48	0.50
	±0.01 ^d	±0.03 ^b	±0.01 ^d	±0.01 ^a	±0.01 ^b	±0.02 ^c	±0.01 ^a	±0.00 ^d
Cu	0.35	0.34	0.37	0.39	0.31	0.34	0.37	0.39
	±0.01 ^b	±0.01 ^d	±0.00 ^c	±0.04 ^d	±0.00 ^a	±0.00 ^d	±0.00 ^b	±0.01 ^a

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285 | Table 3: Anti-nutrient and anti-oxidant content of *Abuja, Efuru*, Sesame seed and enriched
286 flour

Sample	Phytate %	Oxalate %	Saponins %	Tannins %	T. I (TIU/mg)	R P	T P (mg/GAE/g)
AYF	0.03± 0.00 ^b	0.01± 0.00 ^d	0.09± 0.00 ^a	0.00± 0.00 ^a	0.13± 0.01 ^b	0.33± 0.00 ^c	9.31± 0.07 ^d
EYF	0.02± 0.00 ^d	0.01± 0.00 ^b	0.08± 0.00 ^c	0.00± 0.00 ^a	0.09± 0.00 ^d	0.34± 0.00 ^b	9.38± 0.01 ^a
SSF	0.35± 0.00 ^d	0.19± 0.00 ^a	0.22± 0.00 ^b	0.00± 0.00 ^b	19.37± 0.01 ^c	0.83± 0.00 ^d	25.34± 0.01 ^c
1	0.07± 0.00 ^d	0.04± 0.00 ^a	0.10± 0.00 ^b	0.01± 0.00 ^b	0.66± 0.01 ^b	0.36± 0.00 ^c	11.02± 0.00 ^d
2	0.09± 0.00 ^a	0.05± 0.00 ^d	0.11± 0.00 ^d	0.01± 0.00 ^a	0.81± 0.01 ^c	0.38± 0.00 ^c	11.51± 0.00 ^a
3	0.09± 0.00 ^b	0.06± 0.00 ^a	0.11± 0.00 ^b	0.01± 0.00 ^b	1.13± 0.01 ^c	0.40± 0.00 ^a	11.86± 0.01 ^d

4	0.10± 0.00 ^a	0.07± 0.00 ^b	0.13± 0.00 ^c	0.01± 0.00 ^d	1.40± 0.00 ^d	0.43± 0.00 ^b	12.12± 0.00 ^c
5	0.07± 0.00 ^a	0.04± 0.00 ^a	0.10± 0.00 ^c	0.10± 0.00 ^d	0.60± 0.01 ^c	0.83± 0.00 ^a	25.34± 0.01 ^c
6	0.08± 0.00 ^a	0.05± 0.00 ^b	0.11± 0.00 ^c	0.01± 0.00 ^c	0.75± 0.00 ^d	0.40± 0.00 ^b	11.19± 0.00 ^a
7	0.09± 0.00 ^b	0.05± 0.00 ^a	0.12± 0.00 ^a	0.01± 0.00 ^c	1.09± 0.00 ^b	0.41± 0.00 ^a	11.96± 0.00 ^b
8	0.00± 0.00 ^b	0.07± 0.00 ^a	0.13± 0.00 ^d	0.01± 0.00 ^b	1.34± 0.00 ^c	0.43± 0.00 ^d	12.21± 0.01 ^a

287

288 AYP = Abuja yam Flour; EYP = Efuru yam flour; SSF = Sesame seed flour

289 T. I. = Trypsin Inhibitor; R. P. = Reducing power; T. P. = Total Polyphenols

290

291 Table 4: Physico-chemical properties of *Abuja*, *Efuru*, Sesame seed and enriched flour

Sample	LBD (g/ml)	PBD (g/ml)	WAC (g/100g)	OAC (g/100g)	SC (g/g)	LG
AYF	0.49± 0.00 ^b	0.51± 0.00 ^a	127.00± 0.00 ^d	96.00± 0.00 ^b	18.26± 0.00 ^d	21.24± 0.00 ^b
EYP	0.49± 0.00 ^a	0.51± 0.00 ^d	130.00± 0.71 ^d	101.00± 0.71 ^b	18.31± 0.01 ^a	21.18± 0.01 ^b
SSF	0.51± 0.00 ^a	0.54± 0.00 ^d	118.00± 0.71 ^c	80.00± 0.00 ^a	11.64± 7.07 ^d	13.38± 0.00 ^a
1	0.49± 0.00 ^c	0.52± 0.00 ^b	123.00± 7.07 ^d	86.00± 1.02 ^c	12.03± 0.00 ^d	13.70± 7.07 ^d
2	0.50± 0.00 ^b	0.52± 0.00 ^c	131.00± 1.44 ^b	98.00± 1.41 ^b	12.47± 0.00 ^a	13.92± 0.00 ^b
3	0.51± 0.00 ^d	0.53± 0.00 ^b	136.00± 0.00 ^b	98.00± 1.41 ^b	12.49± 0.00 ^a	14.15± 0.00 ^c
4	0.51± 0.00 ^a	0.53± 0.00 ^d	141.00± 0.00 ^a	105.00± 0.00 ^d	12.69± 0.00 ^d	14.26± 0.00 ^d
5	0.49±	0.52±	126.00±	88.00±	12.05±	13.71±

	0.00 ^b	0.00 ^a	0.71 ^d	0.71 ^b	0.00 ^d	0.01 ^d
6	0.50±	0.52±	134.00±	94.00±	12.30±	13.95±
	0.00 ^d	0.00 ^d	0.71 ^d	0.00 ^b	0.00 ^c	0.01 ^c
7	0.51±	0.53±	138.00±	100.00±	12.51±	14.17±
	0.00 ^c	0.00 ^b	0.71 ^a	0.71 ^d	0.01 ^a	0.00 ^a
8	0.51±	0.53±	143.00±	108.00±	14.28±	14.28±
	0.00 ^d	0.00 ^b	0.71 ^b	0.71 ^d	0.01	0.01

292

293 Where:

294 **LBD** = Loose Bulk Density, **WAC** = Water absorption Capacity, **OAC** = Oil Absorption

295 Capacity, **SC** = Swelling Capacity, **PBD** = Packed Bulk Density, **LGC** = Least Gelation

296 Concentration, **AYF** = Efuru Yam Flour, **SSF** = Sesame Seed Flour

297 CONCLUSION

298 Enriching yam flour_s with sesame seed flour significantly improves the proximate, and
 299 mineral composition and the functional properties of the flour_s of two cultivars of yam
 300 studied. The level of anti-nutrient composition of the enriched flour was very low, except the

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301 trypsin inhibitors. However, processing methods cause reduction in the level of trypsin
 302 inhibitors, hence it cannot constitute any hindrance to nutrient absorption and utilisation. The
 303 level of polyphenols in the enriched flour samples will improve the antioxidant properties of
 304 the flour (should go to discussion section). Including sesame seed flour in yam flour can

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305 improve nutrient intakes, dietary diversity and contribute substantially to meeting nutritional
 306 needs of consumers when consumed along other food sources, thereby improving the
 307 nutritional and health status of consumers.

308

309 REFERENCES

310 1. Abou-Gharbia HA, Shahidi F. Effects of processing on oxidative stability of sesame
 311 oil extracted from intact seeds. *J. Amer. Oil Chem. Soc.* 1997;74:215-221.

- 312 2. El Khier MKS, Ishag KEA, Yagoub AEA. Chemical Composition and Oil
313 Characteristics of Sesame Seed Cultivars grown in Sudan. *Research J. of Agriculture*
314 *and Biological Sci.* 2008;4(6):761-766.
- 315 3. Ghandi AP. Simplified process for the production of sesame seed (*Sesamum indicum*
316 *L*) butter and its nutritional profile. *Asian J. Food Agro-Ind.* 2009; 2(01):24-27.
- 317 4. Crews C, Hough P, Godward J, Brereton P, Lees M, Guiet S, Winkelmann W.
318 Quantitation of the main constituents of some authentic grape-seed oils of different
319 origin. *J. Agric. Food Chem.* 2006;54:6261-6265.
- 320 5. Jannat B, Oveisi MR, Sadeghi N, Hajimahmoodi M, Behzad M, Choopankari E,
321 Behfar AA. Effects of roasting temperature and time on healthy nutraceuticals of
322 antioxidants and total phenolic content in Iranian Sesame seeds (*Sesamum indicum L*).
323 *Iran J. Environ. Health. Sci. Eng.* 2010;7(1):97-102.
- 324 6. Hansen R; 2011. Sesame profile. Available at: [http://www.agmrc.org/commodities](http://www.agmrc.org/commodities/products/grainoilseeds/sesameprofile.cfm)
325 [products/grainoilseeds/sesameprofile.cfm](http://www.agmrc.org/commodities/products/grainoilseeds/sesameprofile.cfm).
- 326 7. Borchani C, Besbes S, Blecker CH, Attia H. Chemical Characteristics and Oxidative
327 stability of Sesame Seed, Sesame Paste and Olive Oils. *J. Agri. Sci. Tech.*
328 2010;12:585-596.
- 329 8. NAERLS; 2010. Beniseed production and utilization in Nigeria. Extension Bulletin
330 No 154, Horticulture (5). Available at:
331 www.naerls.gov.ng/extmat/bulletins/Beniseed.pdf.
- 332 9. Fu Y, Huang P, Chu C. Use of continuous bubble separation process of separating and
333 recovering starch and mucilage from yam (*Dioscorea pseudojaponica yamamoto*).
334 *LWT-Food Science and Technology.* 2005;38(7):735-744.
- 335 10. BBC News; 2010. Celebrating Nigeria's Yummy Yam. BBC News Africa (Southern
336 Nigeria). September, 2010.
- 337 11. Osunde ZD. Minimizing post harvest losses in yam (*Dioscorea spp*) treatment and
338 techniques. In G. L. Robertson and J. R. Lupein (eds), using Food Science and
339 Technology to improve Nutrition and Promote National Development. Canada
340 International Union of Food Science and Technology. 2008.
- 341 12. Reuben J, Barau AD. Resource use efficiency in Yam production in Taraba State,
342 Nigeria. *J. of Agricultural Science.* 2012;3(2):71-77.
- 343 13. Omojola JT, Ugwumba COA, Chidebelu SAND. Economic Efficiency and returns to
344 scale of Yam production in Southwest Nigeria. *Inter. J. of Agric. Innovations and*
345 *Research.* 2014;2(6):900-904.
- 346 14. Ike PC, Inoni OE. Determinants of yam production and economic efficiency among
347 small holder farmers in South-eastern, Nigeria. *Journal of Central European*
348 *Agriculture.* 2006;7(2):337-342.
- 349 15. Iwuoha CI. Comparative evaluation of physicochemical qualities of flours from
350 steam-processed yam tubers. *J. Food Chem.* 2004;85:541-551.
- 351 16. Adepoju OT. Effects of processing methods on nutrient retention and contribution of
352 white yam (*Dioscorea rotundata*) products to nutrient intake of Nigerians. *African J*
353 *Food Sci.* 2012;6(6):163-167.
- 354 17. Adepoju OT, Boyejo O, Adeniji PO. Effects of processing methods on nutrient and
355 antinutrient composition of yellow yam (*Dioscorea cayenensis*) products. *Food*
356 *Chemistry.* 2018;238:160–165.
- 357 18. Ihekoronye IA, Ngoddy PO. Integrated Food Science and Technology for the Tropics.
358 Macmillan Educ. Ltd, London and Oxford. 1985;1st edn:pp. 44-46, 160-162.
- 359 19. Ojiako OA, Igwe CU. Nutritional and Antinutritional compositions of *Cleome*
360 *rutidosperma*, *Lagenaria siceraria* and *Cucurbita maxima* seeds from Nigeria. *J.Med*
361 *Food.* 2007;10:735-738.

- 362 20. AOAC. Official methods of analysis. 17th edition. Association of Official Analytical
363 Chemists. Washington D. C., USA; 2005.
- 364 21. Brunner JH. Direct Spectrophotometer determination of Saponin. *Anal.*
365 *Chem.*1984;34: 1314-1326.
- 366 22. AOAC. Official methods of analysis. 14th edition. Association of Official Analytical
367 Chemists. Arlington VA; 1984.
- 368 23. Leach HW, McGowen LD, Schoch TJ. Structure of the starch granule. Swelling and
369 solubility patterns of various starches. *Cereal Chem.* 1959;36:534.
- 370 24. Sathe SK, Deshpande SS, Salunkhe DK. Functional properties of winged bean
371 (*Psophocarpus tetragonolobus*) proteins. *J. Food Sci.* 1959;47:503-506.
- 372 25. Ouilly JT, Bazongo P, Bougma A, Kabore' N, Lykke AM, Oue' draogo A, Bassole'
373 IHN. Chemical composition, physicochemical characteristics and nutritional value of
374 *Lannea kerstingii* seeds and seed oil. *J. of Analytical methods in Chemistry* 2017; 1-6.
- 375 26. Zebib H, Bultosa G, Abera S. Physico-chemical and sensory properties of Banana
376 flour - sesame paste blends. *International Journal of Scientific and Research*
377 *Publications.* 2015;5(4):1-9.
- 378 27. Bamigboye AY, Okafor AC, Adepoju OT. Proximate and mineral composition of
379 whole and dehulled Nigeria sesame seed. *Afr. J. of Food Science and Tech.*
380 2010;1(3):071-075.
- 381 28. Abu-Jdayil B, Al-Malah K, Asoud H. Rheological characterization of milled sesame
382 (*tehineh*). *Food Hydrocolloids.* 2002;16(1):55-61.
- 383 29. Gharehyakheh S, Tavakolipour H. Rheological properties of sesame paste (Ardeh)
384 with different concentration of honey. *Annals of Biological Research.* 2013;4:196-
385 199.
- 386 30. Brough SH, Azam-Ali SN, Taylor AJ. The potentials of Bambara groundnut (*Vigna*
387 *subterranean*) in vegetable milk production and basic milk protein functionality
388 systems. *Food Chem.* 1993;47:277-283.
- 389 31. Lalude LO, Fashakin JB. Development and Nutritional Assessment of a weaning food
390 from Sorghum and Oil-seeds. *Pakistan J. Nut.* 2006;5(3):257-260.
- 391 32. Leiner IE. Implications of antinutritional components in soyabean foods. *Crit.*
392 *Rev. Food Sci Nutr.*1994;34:31-67.
- 393 33. Vasconcelos IM, Siebra EA, Mala AA, Moreira RA, Neto AF, Campelo GJA,
394 Oliveira
395 JTA. Composition, toxic and antinutritional factors of newly developed cultivars of
396 Brazilian soybean (*Glycine max*). *J. Sci. Food Agric.* 1997;75:419-426.
- 397 34. Agbede JO, Aletor VA. Comparative evaluation of weaning foods from Gliricidia and
398 Leucaena leaf protein concentrates and some commercial brands in Nigeria.
399 *J.Sci.Food*
400 *Agric.* 2003;84:21-30.
- 401 35. Bamigboye AY, Adepoju OT. Effects of processing methods on nutritive values of
402 Ekuru
403 from two cultivars of beans (*Vigna unguiculata* and *Vigna angustifoliata*). *African J.*
404 *of*
405 *Biotechnology.* 2015;14(21):1790-1795.
- 406 36. Akinyede AI, Amoo IA. Chemical and functional properties of full fat and defatted
407 *Cassia fistula* seed flours. *Pak. J. Nutr.* 2009;8:765-769.
- 408 37. Enujiugha VN. Supplementation of ogi, a maize-based infant weaning food

410 | with African oil bean (*Pentaclethra macrophylla* [Bbenth](#)) seed. *J.Food Agric. Environ*
411 .
412 2006;4(2):34-38.

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